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Obstacle avoidance training for individuals with stroke: a systematic review and meta-analysis

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ABSTRACT

Objectives To accumulate evidence that obstacle avoidance training alone is effective in improving the locomotor ability of individuals with stroke.
Design Systematic review and meta-analysis.
Setting MEDLINE, EMBASE, CENTRAL, ICTRP and PEDro were searched for related information until December 2018. Two independent reviewers extracted data. Outcome measurement data were subjected to meta-analyses using random-effects models. Data syntheses were conducted using RevMan V.5.3, and the certainty of evidence was determined using the Grading of Recommendations Assessment, Development, and Evaluation approach.
Participants Participants with various types and phases of stroke were included.
Intervention The usual gait training including obstacle avoidance training (interventions of any type, intensity, duration and frequency).
Primary and secondary outcome measures Primary outcomes were gait speed, composite gait ability and objective balance ability. Secondary outcomes were subjective balance ability, gait endurance and fall incidence.
Results Two randomised controlled trials with a total of 49 participants were used as data sources for this study. The obstacle avoidance training (training) group had lower gait speed than the control group (mean difference (MD) 0.03, 95% CI −0.11 to 0.16, p=0.51). Further, the certainty of evidence was very low. The subjective balance ability (Activities-specific Balance Confidence scale) was not significantly different between the training and control groups (MD 6.65, 95% CI −7.59 to 20.89, p=0.36), and it showed very low certainty of evidence.
Conclusions Obstacle avoidance training may have little or no effect on individuals with stroke. The failure to find the effectiveness of obstacle avoidance training alone is possibly attributable to the insufficient amount of training in the intervention and the lack of well-designed studies that measured relevant outcomes.
PROSPERO registration number CRD42017060691.

Strengths and limitations of this study

- ► This is a systematic review and meta-analysis on evidence of the effects of obstacle avoidance training on individuals with stroke.
- ► This study was conducted based on the Cochrane Handbook and the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines.
- ► Literature search and study selection, data extraction and risk of bias assessment were conducted by two independent reviewers.
- ► This study is limited due to the insufficient amount of training in the intervention, and the lack of well-designed studies that measured relevant outcomes.

INTRODUCTION

Individuals with stroke often have impaired gait abilities primarily due to motor paralysis of one side of the body.[1–3] They also have difficulty in maintaining balance, particularly when adaptive locomotor adjustments are necessary in response to environmental properties (eg, obstacle avoidance).[4] In fact, the risk of falling likely increases when individuals with stroke avoid an obstacle.[5–7] Therefore, their gait ability should be improved under various environmental constraints through rehabilitation.

Stroke rehabilitation involves correct recognition of both lost and retained functions. It is also designed to reprogramme the brain by relearning through repetitive task training.[8] The mixed task-oriented circuit class training, including obstacle avoidance training, may promote gait relearning.[9] A previous study demonstrated that gait training and task-oriented training related to gait, such as obstacle avoidance training, improved step distance and gait speed,[9] thus reducing the length of hospital stay.[10] Obstacle avoidance training has been performed as part of the circuit class training, and its effect has been reported in a systematic review.[9]

Gait training with adaptive locomotor training, such as obstacle avoidance training, is usually selected in a clinical setting. Several randomised controlled trials (RCTs) supporting the effectiveness of obstacle avoidance training have been conducted on participants with chronic stroke without combining with any other type of training.[11–14] Furthermore, a systematic review showed the effectiveness of obstacle avoidance training combined with other circuit training.[9] However, the effects produced in the absence of adaptive locomotor training (ie, the intervention effect of the usual gait training) are controversial. To eliminate this issue, whether adaptive locomotor training alone can lead to improved gait ability was investigated in this study. The search for RCTs on obstacle avoidance training for individuals with stroke was conducted to examine its efficacy compared with that of the usual gait training approaches. This review aimed to collect evidence on whether obstacle avoidance training alone is effective in improving the locomotor ability of individuals with stroke.

METHODS

The study protocol has been registered in PROSPERO.[15] This systematic review and meta-analysis was conducted based on the Cochrane Handbook[16 17] and the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines.[18] This study was performed in accordance with the PRISMA checklist (online supplementary table).[19]

The following research question was used: 'Regarding individuals with stroke, does obstacle avoidance training alone result in an improved, clinically relevant outcome compared with the usual care without obstacle avoidance training?'.

Data sources and searches

Systematic searches were conducted using four academic databases: MEDLINE, EMBASE, CENTRAL and PEDro (all searched on 18 December 2018). RCTs in ICTRP were searched on 18 December 2018. These processes are presented in more detail in online supplementary file 1. The references of the extracted studies were also searched in accordance with the guidelines of the following organisations: European Stroke Organisation, American Heart Association/American Stroke Association and National Institute for Health and Care Excellence.[20–22]

Study selection

Two independent reviewers (DM and SO) selected and reviewed studies, and they independently screened the titles and abstracts for study selection to determine whether each citation met the inclusion criteria. They assessed eligibility based on a full-text review. The reviewers compared their lists, and any differences in opinion between them were resolved through discussion.

To be eligible for inclusion in this systematic review, studies had to (1) focus on participants with various types of strokes (brain ischaemia, intracranial haemorrhage or subarachnoid haemorrhage) and on all phases of stroke in affected individuals (acute, subacute or chronic) and (2) perform the usual gait training and include adaptive locomotor training in addition to the usual gait training (interventions of any type, intensity, duration and frequency; training group). Studies with participants with a disease other than stroke or who underwent multiple gait-related training other than obstacle avoidance training, such as circuit class training, were excluded from the study.

The control criterion was a physical therapy intervention such as usual gait training for participants with stroke (control group). The exclusion criteria for the control group were as follows. The control group underwent interventions other than physical therapy if the training group did not undergo the study intervention. The references of extracted articles were also searched, and the authors of each study were contacted to obtain necessary data. The search was limited to published and unpublished RCTs. Crossover trials, cluster randomised trials, non-randomised trials and observational studies were excluded.

The following primary outcomes were measured: (1) gait speed, measured using the 10 m walk test (10MWT) or 6 min walk test (6MWT); (2) composite gait ability, measured using the Timed Up and Go test (TUG)[23]; and (3) objective balance ability, evaluated by researchers and measured according to the Berg Balance Scale (BBS). Secondary outcomes were subjective balance ability, evaluated by participants and measured according to the Activities-specific Balance Confidence scale (ABC); gait endurance, measured using 6MWT; and fall incidence, measured at postintervention 6 months or 1 year.

Data extraction and quality assessment

Data extraction was performed using a standardised form that included participant characteristics (number of participants, number of patients excluded from the analysis and setting), the intervention environment setup (obstacle avoidance, other rehabilitation training and using a virtual reality system), types of outcomes (fall incidence, activities of daily living, gait ability and balance ability) and training programme details (types of exercises, duration and frequency).

Standard data extraction forms were used by the two independent reviewers. Disagreement over data extraction was resolved through discussion. When the information was inadequate, the study authors were contacted to gather sufficient information.

The risk of bias of the included studies was also evaluated using the Cochrane Risk of Bias Tool.[16 17] Each domain was assessed as high risk, low risk or unclear. Assessments were compared by the two independent reviewers, and any differences in opinion between them were resolved through discussion and arbitration by a third reviewer (YK) if consensus was not met. During publication bias evaluation, funnel plot asymmetry was not evaluated because the number of studies was <10; rather, publication bias was evaluated by searching the clinical trial registry.

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Data synthesis and analysis

For continuous outcomes (gait speed, TUG, BBS, ABC and 6MWT), the mean difference (MD) with 95% CI was calculated. MD was used when data, including meta-analysis data, were derived from the same indicators. We originally planned to use the standardised mean difference (SMD) in PROSPERO because the outcomes could be measured on a different scale; however, MD was adopted because the outcomes were measured on the same scale. Adverse events are summarised narratively because the definition of these outcomes varied among studies.

Heterogeneity was assessed by visual inspection of forest plots and calculated using I^2 statistic (I^2 values of 0%–40%: might not be important; 30%–60%: may represent moderate heterogeneity; 50%–90%: may represent substantial heterogeneity; and 75%–100%: considerable heterogeneity).[16 17] Reasons for heterogeneity were investigated whenever identified (I^2 statistic >50%).

Data syntheses were conducted using RevMan V.5.3 (RevMan 2014). A meta-analysis was conducted using a random-effects model. All adverse events were excluded from the meta-analysis. Further, an analysis of intervention versus any other controls was conducted.

Sensitivity analysis was conducted to determine the robustness of the findings. The sensitivity analysis of the primary outcome was planned in the following ways: (1) restricting analysis studies to those with a low risk of selection bias, (2) excluding trials with missing data and (3) converting the random-effects model to a fixed-effects model. Selection bias that may have the largest effect on our research question was eliminated through sensitivity analysis as predefined. Finally, only two RCTs were identified; therefore, other risks of bias did not have to be assessed.

Participant and public involvement

No participants were involved in this study.

Ethical consideration

Institutional review board approval was not necessary because all the data were retrieved from public databases.

RESULTS

Summary of findings

The 'Summary of findings table' was created using outcomes including gait speed, composite gait ability, objective balance ability, subjective balance ability and gait endurance (table 1). The five Grading of Recommendations Assessment, Development, and Evaluation (GRADE) considerations (study limitations, consistency of effect, imprecision, indirectness and publication bias) were used to assess the certainty of evidence because they

Table 1 Summary of findings

Outcome (time frame)	No of participants (studies)	Certainty of evidence (GRADE)	Comparator	Training versus control Mean difference (95% CI)
Gait speed (m/s) (3–4 weeks)	49 (2 RCTs)	⊕⊖⊖⊖ Very low*†‡	The mean gait speed after treadmill gait training without obstacle crossing in real-life situations ranged from 0.71 to 0.95 m/s	0.03 m/s (95% CI −0.11 to 0.16) faster in the training group
Composite gait ability TUG (s) (4 weeks)	29 (1 RCT)	⊕⊕⊖⊖ Low*†	The mean time of TUG after treadmill gait training without obstacle crossing in real-life situations was 15.37 s	0.15 s (95% CI −3.95 to 4.25) faster in the training group
Objective balance ability BBS score (4 weeks) Scale: 0–56	29 (1 RCT)	⊕⊕⊖⊖ Low*†	The mean score of BBS after treadmill gait training without obstacle crossing was 46.14	−0.03 score (95% CI −2.01 to 1.95) higher in the training group
Subjective balance ability ABC score (3–4 weeks) Scale: 0–100	49 (2 RCTs)	⊕⊖⊖⊖ Very low*†‡	The mean score of ABC after treadmill gait training without obstacle crossing in real-life situations ranged from 62.58 to 72.23	−6.67 score (95% CI −20.97 to 7.58) higher in the training group
Gait endurance 6MWT (m) (4 weeks)	29 (1 RCT)	⊕⊕⊖⊖ Low*†	The mean gait distance after treadmill gait training without obstacle crossing was 277.43 m	−5.40 m (95% CI −36.59 to 25.79) longer distance in the training group

GRADE Working Group grades of evidence.
High quality: further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: the estimate is very uncertain.
*Participants and personnel were not blinded.
†The number of participants was small.
‡The outcome data were incomplete for 10% of participants.
ABC, Activities-specific Balance Confidence scale; BBS, Berg Balance Scale; 6MWT, 6 min walk test; RCTs, randomised controlled trials; TUG, Timed Up and Go test.

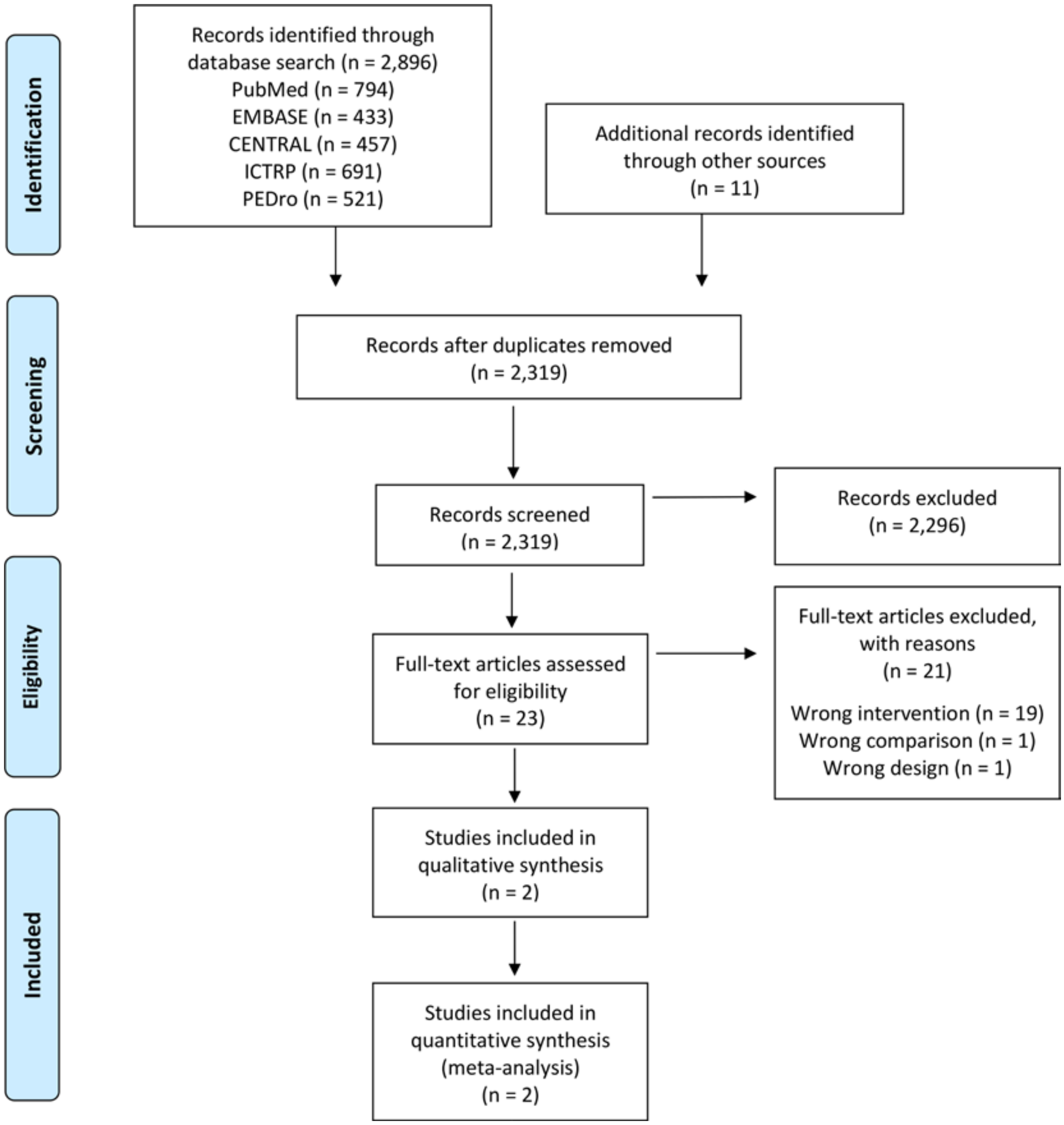

Figure 1 Flow diagram for Preferred Reporting Items for Systematic Reviews and Meta-Analysis.

are related to studies contributing data for the review of outcomes.[16 17 24 25]

PRISMA flow diagram

The process of identifying eligible studies is outlined in figure 1. A total of 2319 articles (including titles and abstracts) were identified from MEDLINE, EMBASE, CENTRAL, ICTRP, PEDro and manual search using the following search terms: stroke, obstacle, avoidance, task, exercise, rehabilitation and training. Twenty-three potentially eligible articles were included. After reviewing the full text of these 23 potential articles, 2 articles[13 14] met the inclusion criteria. Nineteen of the remaining 21 articles were excluded because their studies included several other forms of gait training (eg, circuit class training and task-oriented training). From the remaining two studies, one[11] was excluded because obstacle avoidance training was not compared with the usual gait training; however, both groups participated in obstacle avoidance training (in water vs on the ground). The other study[12] was excluded because of a wrong design (a cross-sectional study that assessed participant characteristics in various environments including obstacle avoidance). Moreover, there was no related ongoing study.

Two articles[13 14] with a total of 54 participants met the inclusion criteria, and 2 articles with a total of 49 participants were used as data sources for the present meta-analysis (figure 1). The discrepancy between the number of participants included in the meta-analysis and the total number of participants is due to some dropouts from the meta-analysis: four dropouts from the study by Yang[14] and one from the study by Jeong.[13] The characteristics of each included study are presented in table 2. The details of the risk of bias assessment are outlined in table 3. In both studies, participants were not blinded to the intervention. Moreover, the studies had incomplete outcomes. One study[13] reported an unknown risk

Table 2 Characteristics of the included trials

Author, year, country	Setting	No of participants (phases of stroke)	Study type	Training (contents, frequency)	Control (standard care)	Outcomes
Yang *et al*,[14] 2008, Taiwan	Exercise laboratory	24 (chronic) training: 12, control: 12	Pilot RCT	Virtual reality-based treadmill training: scenarios comprised lane gait, street crossing, obstacles striding across and park stroll Intervention for 20 min/session, 3 sessions/ week for 3 weeks	Treadmill training without virtual reality	Gait speed (10MWT), community gait time, Walking Ability Questionnaire and ABC
Jeong *et al*,[13] 2016, Korea	Exercise laboratory	30 (chronic) training: 15, control: 15	Pilot RCT	Treadmill gait with obstacle crossing in real-life situations Intervention for 30 min/day, 5 times/week, for 4 weeks	Treadmill gait without obstacle crossing	10MWT, 6MWT, BBS, TUG and ABC

ABC, Activities-specific Balance Confidence scale; BBS, Berg Balance Scale; 6MWT, 6 min walk test; 10MWT, 10 m walk test; RCT, randomised controlled trial; TUG, Timed Up and Go test.

of bias from published data; therefore, the authors were contacted. According to the authors, they had planned to measure the three-axis accelerometer and quality of life. However, considering several circumstances and patient conditions, they did not measure these outcomes.

Primary outcomes

Pooling revealed that the group that underwent obstacle avoidance training (training group) was not superior to the control group in terms of gait speed (MD 0.03, 95% CI −0.11 to 0.16, p=0.51) (figure 2A). Regarding gait speed, no heterogeneity was observed (Tau^2=0.00, I^2=0%). Data on composite gait and objective balance abilities were available in 1 of the 3 RCTs. MD (95% CI) for TUG was 0.15 (−3.95 to 4.25) (figure 2B) and that (95% CI) for the BBS scores was −0.03 (−2.01 to 1.95) (figure 2C). Sensitivity analysis results were approximately the same as the original results (table 4).

Secondary outcomes

The subjective balance ability (ABC) was not significantly different between the training and control groups (MD −6.67, 95% CI −20.92 to 7.58, p=0.36) (figure 3A), and substantial heterogeneity was observed (Tau^2=89.62, I^2=83%). Data on gait endurance were available for one of the two studies,[13] whereas data on fall incidence were not available from any study. MD (95% CI) for 6MWT was −5.40 (−36.59 to 25.79) (figure 3B).

There were no reports of adverse events during the intervention in any of the three studies.

DISCUSSION

Summary of findings

Two RCTs that met the inclusion criteria were found. Their certainty of evidence was low or very low due to serious study limitations and imprecision. The present meta-analysis showed that obstacle avoidance training alone cannot improve gait speed or subjective balance ability compared with the usual gait training.

Comparison with the literature

There are at least two reasons for the failure to determine the effectiveness of obstacle avoidance training alone. First, the amount of training was insufficient for both included RCTs. According to a systematic review on circuit class training, the duration of the training was ~60 min in a single session, and various gait-related training tasks were continuously performed.[9] In contrast, the duration of obstacle avoidance training was only 20–30 min in the present study (table 2). No difference was observed in training frequency (3–5 times/week) was observed between the circuit class training and obstacle

Table 3 Risk of bias assessment in the included trials

Trial	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective reporting
Yang *et al*, 2008[14]	Unclear	Low	High	Low	High	Unclear
Jeong *et al*, 2016[13]	Low	Low	High	Low	High	Low

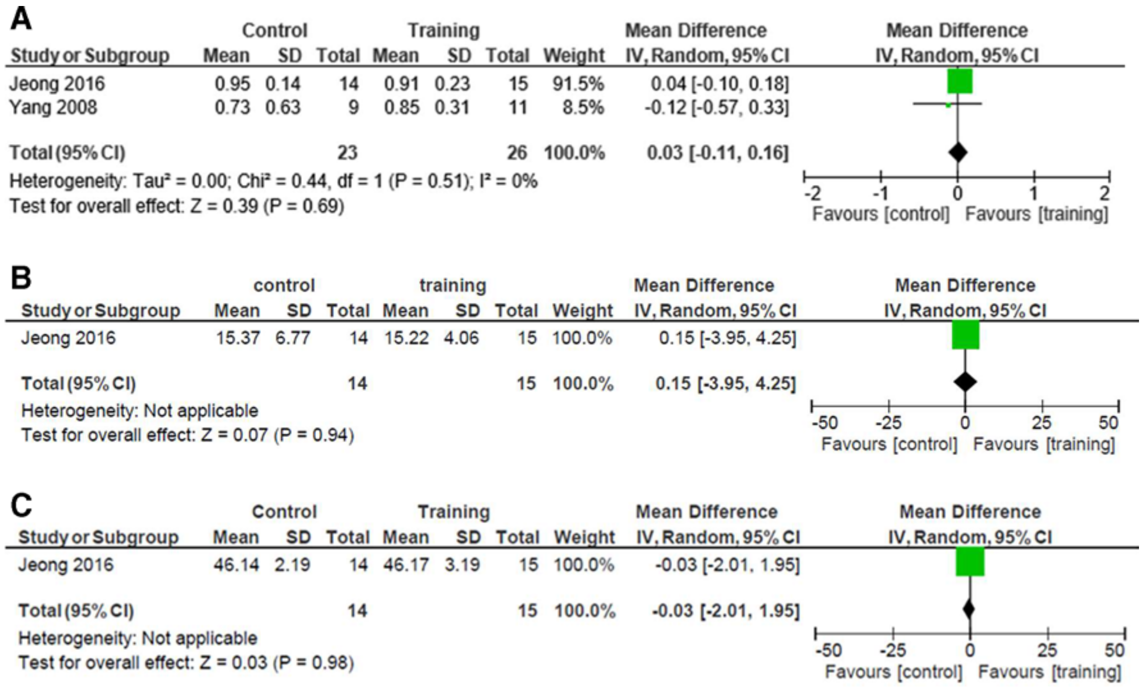

Figure 2 Primary outcomes. (A) Effects of obstacle avoidance training on gait speed. (B) Effects of obstacle avoidance training on composite gait ability (TUG). (C) Effects of obstacle avoidance training on objective balance ability (BBS score). BBS, Berg Balance Scale; TUG, Timed Up and Go test.

avoidance training groups. A previous RCT showed that their lower limb training group (gait training in addition to usual gait training; upper and lower limb training for the functional recovery of activities of daily living or gait training) significantly differed from their control group (upper limb training or no training in addition to the usual gait training) in terms of gait ability.[26] In the meta-analysis, the momentum of the lower limbs increased to improve gait speed and endurance.[10 27] Therefore, an insufficient trial period may not be able to demonstrate the effectiveness of obstacle avoidance training alone.

The second reason would be the lack of well-designed studies that measured relevant outcomes such as fall incidence and composite gait ability. Indeed, to date, no study has examined fall incidence, whereas only one study has examined composite gait ability. In addition, obstacle avoidance ability (eg, success rate, avoidance reaction time and foot clearance) was not measured in the included RCTs for individuals with stroke. A previous systematic review on elderly individuals showed that the effect of physical training was evaluated based on obstacle avoidance ability.[28] A previous observational study on individuals with stroke reported that obstacle-crossing training led to improved obstacle avoidance ability as one aspect of the gait adaptability training for individuals with stroke.[29] However, no outcome related to obstacle avoidance ability is reported in this systematic review and meta-analysis. Therefore, this study suggests that obstacle avoidance training alone has little or no effect on improving gait or balance ability.

Strengths and limitations

The strengths of this study are (1) that, to the best of our knowledge, this is the first systematic review and meta-analysis on the evidence of effects of obstacle avoidance

Table 4 Results of the sensitivity analysis for each primary outcome

Primary outcomes	Analysis 1: restricting the analyses on studies with low risk of selection bias		Analysis 2: excluding trials imputed with missing data		Analysis 3: converting a random-effects model to a fixed-effects model	
	No of RCTs	Result	No of RCTs	Result	No of RCTs	Result
Gait speed	1 RCT (Jeong, 2016)[13]	0.04 (–0.10 to 0.18)	2 RCTs (Yang, 2008,[14] Jeong, 2016)[13]	0.03 (–0.11 to 0.16)	2 RCTs (Yang, 2008,[14] Jeong, 2016)[13]	0.03 (–0.11 to 0.16)
TUG	1 RCT (Jeong, 2016)[13]	0.15 (–3.95 to 4.25)	1 RCT (Jeong, 2016)[13]	0.15 (–3.95 to 4.25)	1 RCT (Jeong, 2016)[13]	0.15 (–3.95 to 4.25)
BBS	1 RCT (Jeong, 2016)[13]	–0.03 (–2.01 to 1.95)	1 RCT (Jeong, 2016)[13]	–0.03 (–2.01 to 1.95)	1 RCT (Jeong, 2016)[13]	–0.03 (–2.01 to 1.95)

BBS, Berg Balance Scale; RCTs, randomised controlled trials; TUG, Timed Up and Go test.

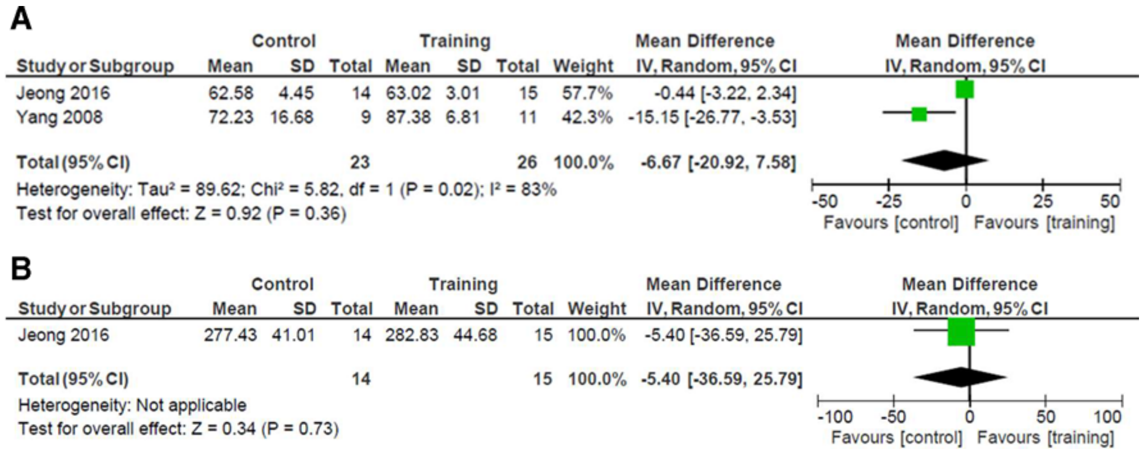

Figure 3 Secondary outcomes. (A) Effects of obstacle avoidance training on subjective balance ability (ABC). (B) Effects of obstacle avoidance training on gait endurance (6MWT). 6MWT, 6 min walk test; ABC, Activities-specific Balance Confidence scale.

training on individuals with stroke and (2) its careful and rigorous screening, extraction and scoring.

This study has certain limitations. Most studies had a high or unclear risk of bias, and the number of RCTs was small. Although a well-designed study[13] showed an improvement in gait endurance and objective balance ability, the effects of the intervention on these parameters in the training group were not superior to those in the control group in the present systematic review and meta-analysis. Based on these results, determining the influence of the intervention on improved gait and balance abilities was difficult.

Another limitation is that none of the two included RCTs evaluated obstacle avoidance ability itself (eg, toe clearance and success rate of obstacle-crossing training). Therefore, the intervention effect of obstacle avoidance training may have been masked. In the future, RCTs with a low risk of bias, including an assessment of obstacle avoidance ability, should be accumulated to verify our findings. Because stroke rehabilitation aimed to improve gait ability under various environmental constraints, the effect of obstacle avoidance training (other than those of step over training) should be confirmed. In the future, RCTs on obstacle avoidance training including gait through apertures (including the fall incidence and obstacle avoidance ability) should be conducted.

As a clinical limitation, obstacle avoidance training as a single task is not useful according to the best available evidence; accordingly, other interventions such as using combinations of training and increasing the amount of gait training should be considered.[30–32]

Clinical implications and recommendations

Confirming the effects of obstacle avoidance training on individuals with stroke is highly clinically important because these individuals are more likely to fall while avoiding an obstacle. However, none of the outcomes was found to be significantly altered after obstacle avoidance training. We currently recommend that rehabilitation workers should allow individuals with stroke to practice other gait training and obstacle avoidance training.

CONCLUSIONS

This systematic review and meta-analysis showed that obstacle avoidance training in addition to the usual gait training for individuals with stroke may have little or no effect. The failure to determine the effectiveness of obstacle avoidance training alone may be due to the insufficient amount of training in the intervention and the lack of well-designed studies that measured relevant outcomes, such as fall incidence, composite gait ability and obstacle avoidance ability. Further research is required to identify the effects of obstacle avoidance training alone.

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Contributors DM, YK, MB, YT and HT conceived the study. DM drafted the protocol manuscript, and all authors revised it. DM and YK designed the search strategies, and DM and SO performed the searches and screened studies for inclusion, extracted the data and assessed the risk of bias of included studies. YK arbitrated disagreements between reviewers. DM, SO and YK analysed and interpreted the data. All authors have provided conceptual and/or methodological expertise. DM, YK, MB, YT and TH have contributed to the critical revision of this manuscript for important intellectual content. All authors agreed to be accountable for all aspects of the work and have read and approved the final manuscript.

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